SOLUBLE POTASH FROM INSOLUBLE IGNEOUS ROCK

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

1916

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A PROCESS FOR THE PRODUCTION OF SOLUBLE POTASH FROM INSOLUBLE IGNEOUS ROCK.

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A Thesis

Presented by

GEORGE BERNARD PERLSTEIN

and

HENRY BERNARD WILKENS

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26427

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I.

INTRODUCTION.

The importance of potassium and potash salts was neither understood nor appreciated by the American public until the German-American potash war of 1909 - 1910. Since that time interest has been aroused and potash has been the subject of much lively discussion and investigation. With the outbreak of the present European war and its attendant stoppage of German exports, there came a great rush on the part of the seekers of potash. Farmers needed it perhaps more acutely than any one else, for potassium is absolutely essential to plant growth, and it is one of those elements which the cultivated plant uses faster than nature can supply. Aside from agricultural uses, the soap, match, glass-making, photographic, pharmaceutical and general chemical industries have felt acutely the present potash famine.

The magnitude of the usual imports is shown by the following table taken from the

United States Geological Survey. This table does not include kainite and other potassium manure salts, whose value was at least equal to those quoted below.

Potash salts imported into United States for calender years 1911-1914.

Year	Quantity	Value
1911	670,122,385 lbs.	$11,783,381
1912	622,179,164 "	10,692,285
1913	612,514,916 "	10,805,720
1914	485,818,459 "	8,743,973

The figures for 1914 show a decrease; this was due to the inability to import salts from Germany soon after the declaration of war, in August 1914.

The glass industry uses considerable quantities of potassium carbonate, the cyanide finds wide application in metallurgy and the metallurgical arts, the nitrate in explosives, and the sulphate and chloride in agriculture. These interests and the United States Geological Survey

and the Bureau of Soils of the Department of Agriculture have carried on extensive searches for potash deposits or possible sources of potassium, and they have met with some degree of success.

One of the earliest proposed sources investigated by the Bureau of Soils was the giant kelp of the Pacific Ocean. The government has done splendid work in charting these beds and in securing other data. The beds are nearly continuous from Vancouver to San Diego, with concentrated areas off Los Angeles and Seattle, and other points. The American Products Company at Long Beach, Cal. claims to have successfully made nearly pure potash salts, and several other companies have met with more or less success.

Another source of potash on which the government has rendered a report is Searles Lake, Cal., where there is a large dry lake of several square miles extent. Here wells have been sunk and brine pumped up containing about 10.75% KCl.

The problem of separating the potassium salts from this brine has been very earnestly worked on, and seems in a fair way to achieve ultimate commercial success.

The Geological Survey uncovered extensive deposits of alunite, a hydrous sulphate of aluminum and potassium, which it recommends as a fertilizer, when finely ground, and as a possible source of alumina. These deposits are located in Utah near Marysvale, and on the west slope of the Tushar Mountains. One company, namely the Mineral Products Co., at Marysvale, has been making regular shipments of potassium sulphate since the fall of 1915. Whether or not this will be commercially available under normal conditions remains to be seen.

Perhaps the most useful work the government accomplished in their researches was the discovery and mapping of great feldspar deposits. Potassium oxide makesup about 2.8% of the earths crust, from which at first sight it would seem a

most abundant commercial body. This, however, is not the case. In order that potassium salts be of value, they must be water soluble. Nearly all of the potash in nature is securely held in a most insoluble form in the feldspars and leucites. With the enormous deposits and widespread distribution of these rocks, and their low cost, it is apparent that it would be highly desirable to devise commercial means for the production of soluble potash from them.

The problem and attempt of the writers was to devise and test a profitable process for the production of soluble potassium salts from an insoluble igneous rock. The rock worked on comes from Georgia, and seems to be particularly suited to commercial operations, because of certain characteristics that will be discussed later.

ACKNOWLEDGEMENT.

We are indebted to Professor Harry McCormack for many helpful suggestions. To Dr. C. A. Tibbals, we wish to express appreciation for help given in devising the method of analysis used, and for the kindly interest shown in our work.

PREVIOUS WORK.

The present problem has attracted workers for many years. In 1856 Bickel (U. S. Patent 16,111) proposed a method whereby a mixture of feldspar, lime and phosphatic rock was heated to a bright red heat, and potash salts recovered by leaching. This process has not yet proved practical or successful.

Ward, an Englishman, took out British Pat. 3,185 during the next year. He proposed mixing the finely ground feldspar with powdered fluorspar or other fluorides together with chalk and lime, holding the mass at a red heat for several hours and lixiviating with hot water. As far as is known, no further work has been done along this line.

The processes of nature, the slow action of moisture and atmospheric agencies, particularly the action of carbonic acid gas, are known to have a decomposing effect upon the feldspars. Blackmore (U.S. Patent 772,206), in 1904, proposed to hasten this by subjecting a cream of the ground

powder to the action of carbon dioxide gas under five hundred pounds pressure, applied intermittently and repeatedly for several hours. The alkali was supposedly converted into the carbonate. Ten years previous to this the same investigator (U.S. Pat.513,001) had proposed using lime, calcium chloride and steam pressure in an autoclave, to produce alkali chloride. Neither of these processes have been shown to possess industrial possibilities.

Several workers proposed to bring the potash into solution by means of alkali or alkali-earth hydrates, under pressure.

Gibbs' process consisted of a treatment with hydrofluoric and sulphuric acids, to produce potassium sulphate. Cushman was granted a patent covering a process wherein a sludge of finely ground feldspar in water was treated with a small amount of hydrofluoric acid and the mixture electrolized in wooden cells provided with wooden diaphragms. None of these processes are yet commercially feasible.

Another general method is that in which the feldspar is finely ground, thoroughly mixed with gypsum, carbon, lime, or similar substances, the mix heated and the potash salts volatilized and collected, either in flues or water. Some of the processes, under this heading have been tried on a large scale. No great difficulty is recorded in driving off the potash in the furnace, but obstacles were encountered in collecting the potash from the gases. As a by-product operation in cement manufacture, these processes may yet become industrially important.

Proposed Extraction Processes Chronologically Arranged.

Process.	Year	Deviser	Product
Lime, $Ca_3(PO_4)_2$, red heat	1856	Bickell	KOH
Fluorides, chalk, lime, red heat.	1857	Ward	K_2CO_3
Lime, $CaCl_2$, H_2O, steam	1894	Blackmore	KCl
Lime, salt, heat under melting.	1800	Rhodin	KCl
$Ca(OH)_2$ or NaOH, pressure 16 atmospheres.	1904	Levi (leucite)	K_2SiO_3
H_2SiF_6 & H_2SO_4	1904	Gibbs	K_2SO_4
CO_2, 500 lbs. pressure, repeatedly.	1904	Blackmore	K_2CO_3
KOH, NaOH, steam 25 atm.	1905	Piva (leucite)	K_2SiO_3
Alkali, C, CaO, red heat (leucite)	1905	Soc. Romana Solfati.	K_2CO_3
Gypsum, C, fuse, volatilize	1905	Swayze	K_2SO_4
Lepidolite, K_2SO_4, H_2SO_4	1907	Wadman	K_2SO_4
Water & HF electrolysis	1907	Cushman	KOH
Heated till amorphous then with KOH under pressure.	1907	Swayze	(K_2SiO_3 (K_3AlO_3
Containing mica, with CaO NaCl, and C.	1907	McKee	KCl

Process.	Year	Deviser	Product
Calcine, drive off SO_3 & leach	1908	Dion et fils (alunite)	K_2SO_4
$Ca(OH)_2$, steam 150 lbs.pressure	1909	Gibbs	KOH
Green sand cement mix volatilize	1909	Spencer & Eckel	K-salts
Bacterial action	1910	Coates	
Intense heat, sudden cooling alone.	1910	Carpenter	
CaO, $CaCl_2$, etc.,clumps red heat	1911	Cushman	KCl
$NaHSO_4$, NaCl, bright red heat	1911	Thompson	K_2SO_4
$BaSO_4$ & C, fuse, H_2SO_4 leach	1911	Hart	K-alum
Cement mix not over 1900°C. with green sand volatilize	1911	Eckel	(K-metallic ((K_2SO_4
Heat with coal, Fe, another reducing agent.	1911	Lindblad	
Green sand $CaCO_3$, and C melt	1911	Eckel	K_2SO_4
H_2SO_4, H_2O & CaO, heated	1912	Foote & Scholes	K_2SO_4
Calcine, K or Na_2CO_3, steam 5 atm. Press leach pass CO_2	1912	Peacock	K_2CO_3
Alkali sulphate, air & S compd.	1912-3	Neil	
CaO, $CaCl_2$, with or without NaCl, heat and leach.	1912	Cushman & Coggeshell	KCl

Process	Year	Deviser	Product
$CaCO_3$, heat 1300-1400°C	1912	Peacock	K_2CO_3
Volatilize K comps. in blast furnace	1912	Schneider	
Gypsum, heat to 1600°, NaCl, heat	1912	Morse & Sargent	KCl
Heat with NaCl	1913	Bassett	KCl
Alunite heated and leached	1913	Waggaman	K_2SO_4
HF, heat with $CaSO_4$	1914	McIlhiney	K_2SO_4
$NaHSO_4$, NaCl, C, heat	1914	Bassett	K_2SO_4
Heat with freshly ppted. $CaCO_3$.	1914	Messerschmitt	K_2CO_3
Fuse with $CaCO_3$ & $CaCl_2$, volatilized and collected.	1915	Brown	KCl
Heat with $CaCO_3$ or $CaSO_4$, leach with H_2SO_4.	1915	Coolbaugh & Quinney	K_2SO_4
Heat with C in atm. of N to 1200-1400°C.	1915	Peacock	(K-cyanide (K-nitride
Alunite heated with C, K_2O volatilized and condensed.	1915	McDowell	
Mixed with C & NaCl in bath of H_2SO_4, then roast.	1915	Melkman	

Process	Year	Deviser	Product
CaO, with or without $CaCl_2$, fume off KCl.	1915	Spencer	KCl
Alunite roasted with CaO and leached-1915.	1915	Morgan	K_2SO_4
$CaCO_3$, $CaSO_4$, heated and leached.	1915	Heyman	KOH
Calcined alunite leached with hot water under pressure.	1916	Hagedorn	K_2SO_4

Acknowledgement:- We are indebted to Cushman & Coggeshall for this table through the year 1911.

Several workers, among whom are Thompson and Hart, claim success in producing potassium sulphate. Thompson heats to a bright red a mixture of feldspar, sodium acid sulphate and sodium chloride, and subsequently leaches out the sulphate. Hart in 1911 (U.S. Pat. 997,761) fused feldspar with barium sulphate, together with carbon, pulverized the cooled melt and extracted the product with dilute sulphuric acid, thus producing a solution of potash alum, and a residue of barium sulphate and silica, which is claimed to be useful as a paint pigment. Neither of these processes has attained commercial success.

The process which appears to meet with most favor is that of Cushman and Coggeshall, whereby potassium chloride is produced. Their process is best described by themselves, as follows:-

"This process has recently (Nov.1912) been given extensive trials on a large scale and interesting results have been obtained. The process consists essentially in powdering 100 parts of potash feldspar rock together with about 20 parts of

lime and with or without 10 to 20 parts of rock salt. This powdered mixture is fed to the top of a moving drum about three feet in diameter, in a layer about half an inch deep. As soon as the layer is formed a strong solution of calcium chloride is applied from a series of small tubes. The calcium chloride at once unites with the brine, forming a so-called oxychloride cement and a large portion of the mixed powder is thereby at once formed into "clumps" or aggregates lying in a bed of surplus powder. As the drum revolves the bed is removed by a scraper to a belt that delivers the mixture to a screen which separates the clumps from the residual powder. The powder is returned by a screw conveyor and elevator to the hopper above the drum again. The clumps are about the size of peas and pass from the screen directly to a rotary kiln similar to those used in burning Portland Cement. The kiln is heated by a blast of air and powdered coal, in the usual manner.

The clumps pass regularly down through the increasingly heated portions of the rotating kiln and roll out at the other end, practically without alteration in size and shape.

A large percentage of the total potash present in the feldspar is converted into potassium chloride during the heat treatment, and very little is volatilized. The dry clumps are of a pale yellow color outside, due to the iron in the ash of the bituminous coal used, but they are snow-white inside. The clumps are finely ground, producing a pale yellow material containing as much water-soluble potassium oxide as hardwood ashes, although the potash is in the form of chloride, the product also contains considerable free lime. Up to the present time no attempt has been made on a large scale to leach out the soluble potash. The ground material is being given field tests as a straight potash fertilizer containing lime." Journ. Industrial Engineering Chemistry, volume 4, page 824.

These men have probably done the best work on the subject and have brought it nearest a commercial possibility. They operated on a mill scale and have shown a profit on prices slightly above normal. At the present phenomenal advance in price of potash

the profits would be very great.

From the large number of proposed methods of extraction of potash from feldspar only one, that of Cushman & Coggeshall, has been demonstrated to be cokmercially feasible. All others are either too expensive to operate or depend on the marketing of some by-product, like cement, to succeed, and then on a very narrow margin of profit.

EXPERIMENTAL WORK.

The present investigators were strongly attracted to the use of calcium chloride and calcium carbonate as reactive agents. Both of these are very cheap; in fact, the chloride is a waste product of the Solvay soda process, where its disposition is sometimes an annoying factor. Calcium carbonate was used rather than lime because of the stirring and mixing action of the carbon dioxide liberated from the carbonate at the elevated temperatures employed. At those temperatures, just below 1000°C., there is little possibility of any reaction between the carbon dioxide and the rock, though such a reaction would be highly desirable.

It is of course essential that the analysis of the rock be known before definite calculation can be made and the working charges made up. The analysis of the rock is as follows:-

Moisture	0.40%
Loss on Ignition	3.18%
Na_2O	0.32%
K_2O	10.31%
CaO	0.00%
MgO	1.15%
Al_2O_3	34.94%
Fe_2O_3	1.04%
FeO	2.00%
MnO	0.00%
TiO_2	0.20%
SO_3	0.07%
P_2O_5	trace
CO_2	0.00%
SiO_2	46.75%
Total	100.36%

THEORETICALLY DEDUCED MIXTURES

The first mixture was made up on theoretical considerations; calculations were based on the fact that that substance forms first which has the highest heat of formation. In accordance with this principle, a union of lime and alumina should first take place, to form a calcium aluminate. Sufficient calcium carbonate must be supplied to give the proper amount of lime to react with alumina in one unit, i.e. 100 grams of rock, according to the equation

$$Al_2O_3 + 3\ CaO \rightarrow Ca_3Al_2O_6$$

$$\therefore \quad Al_2O_3 \equiv 3\ CaCO_3$$

$$103 : 3 \times 100.07 :: 34.94 : x$$

$$x = 102.84 \text{ g. } CaCO_3$$

The silica was calculated as going to calcium silicate, according to the reaction

$$CaO + SiO_2 \rightarrow CaSiO_3$$

$$\therefore \quad SiO_2 \equiv CaCO_3$$

$$60.3 : 100.07 :: 46.75 : x$$

$$x = 77.58 \text{ g. } CaCO_3$$

Sodium and potassium chlorides were expected to be formed by the action of hydrochloric acid gas resulting from the decomposition of calcium chloride

by water:-

$CaCl_2 + H_2O \rightarrow CaO + 2\ HCl$

$K_2O + HCl \rightarrow 2\ KCl + H_2O$

$Na_2O + 2\ HCl \rightarrow 2\ NaCl + H_2O$

$K_2O = CaCl_2$

$94.2 : 110.97 :: 10.31 : x$

$x = 12.15$ g. $CaCl_2$ required by the potash.

$Na_2O = CaCl_2$

$62 : 110.97 :: 0.32 : x$

$X = 0.57$ g. $CaCl_2$ required by the soda.

Total $CaCl_2 = 12.15 + 0.57 = 12.72$ g. $CaCl_2$.

The magnesia was considered as acting like lime, and would therefore need nothing to flux it. Other metallic oxides are there in such form that they would not interfere in the process; they are also very small in amount.

A total charge per 100 g. of rock was

$CaCl_2$.....12.75 g.

$CaCO_3$ + 5% excess 190 g.

The rock and limestone were crushed and ground to pass a 100 mesh sieve.

The method of incorporating 12.75 g. of Calcium Chloride in nearly 300 g. of powder next engaged out attention. But one method could logically be applied, namely, that of Cushman. The salt was put into such quantity of water as would just dampen the entire mass and cause it to form small lumps of one-quarter to one-half of an inch in diameter. This was the method pursued throughout the entire work.

The optimum temperature was decided upon after a survey of the literature as being from 900 to 1,000°C. A little above 1,000°C potassium chloride begins to volatilize, a condition which we consider highly undesirable. Though there are proposed processes for the recovery of potassium salts from flue dust produced in cement manufacture or similar operations, none of them have been successful.

In order to determine what time of heating gave best results, a series of three runs was made

all of theoretical proportions, and all in duplicate. Table I shows the results:-

Table I.

Time (hours)	Mean Temp. °C.	Rock (grams)	$CaCO_3$ (grams)	$CaCl_2$ (grams)	Water sol. alk. calc. to K_2O.	% recovery.
1	950	100	190	12.75	1.065	9.86
2	950	100	190	12.75	1.121	10.38
3	950	100	190	12.75	0.946	8.76

These results indicated that a theoretical mixture could not be used, and that heating for two hours gave the best results, though differences in results for different times were not striking. Two hours is about the time that it would take the material to pass through a cement kiln, such as would most probably be used in the practical operation of this process. This time was taken as the best, and all subsequent runs were made on this basis.

METHOD OF OPERATION

A complete run was made in the following manner:-

The required amounts of rock and limestone were weighed, to a gram, on a pulp balance, mixed to a homogeneous powder, and the requisite amount of calcium chloride in proper solution stirred in. The mass was mixed thoroughly until clumps were formed and the whole was damp. This was then charged into an iron dish one and three-quarters inches deep, five inches wide and seven inches long, and placed in a Stewart gas furnace. The temperature was rapidly brought up to the desired point and held there for the proper length of time. Frequent temperature readings were made by means of a Thwing radiation pyrometer, and the contents of the dish stirred from time to time. All heats were made in duplicate. Clay dishes were employed in the first attempt, but these broke after one heat. Iron dishes were thereafter resorted to, with better success.

At the expiration of the proper time the dishes were removed from the furnace and their contents dumped, while hot, into a pan of water. Lumps were broken up by means of a spatula, the mass boiled, settled, and the supernatant liquor poured into a ten-inch evaporating dish. Washing was repeated for a total of four times; the leaching solution was concentrated, filtered into a liter volumetric flask, and made up to the mark. An aliquot portiom of this was taken for analysis. The residue from leaching was discarded, since it serves no purpose.

METHOD OF ANALYSIS

Such volume of solution was taken from the liter flask as would correspond to one gram of original sample of rock. Thus, in No.I, 100 grams of rock were taken, therefore 10 cc. of solution represented 1 gram. To this was added ammonium hydroxide and ammonium carbonate in excess, the solution boiled and filtered. This was put aside; the precipitate was dissolved in dilute hydrochloric acid, and re-precipitated as before. This took out most of the calcium. The first and second filtrates and washings were combined, concentrated, and ammonium oxalate added, the solution boiled and let stand for at least an hour, but preferably over night. The precipitate of calcium oxalate was filtered off, the solution evaporated dry and all ammonium salts expelled by baking. The residue was taken up in water, and an excess of barium hydroxide added, thus removing magnesium as the hydroxide, and sulphur trioxide as barium sulphate.* If sodium and potassium were to be separately determined, the

procedure would now be to filter, remove excess barium from solution with ammonium carbonate. The filtrate would be acidified with hydrochloric acid, (in a platinum dish) evaporated dry, ammonium salts expelled as before, a little hydrochloric acid added, evaporated again, and combined sodium and potassium chlorides weighed. Separation of sodium and potassium would then be made in the usual manner, using the chlorplatinic method.

*In our case, where the amount of sodium was so small, and where combined alkalis gave the desired information, time was saved by following a slightly different procedure after the removal of magnesium hydroxide and barium sulphate.

Excess barium was removed by the addition of a slight excess of sulphuric acid, the barium sulphate filtered, and the filtrate caught in a platinum dish. This was evaporated dry, ignited at a dull red heat, and combined alkalies weighed as sulphates. There is some advantage gained in working with the alkali sulphates rather than the

chlorides, in that the latter decrepitate at a lower temperature than the sulphates and require greater care in their handling.

EMPIRICAL METHODS.

Theoretical combinations giving unsatisfactory results, a series of empirical mixtures were run, varying the amounts of calcium chloride and calcium carbonate for unit amounts of rock, with results as shown in the table:-

Table II.

No.	Time (hours)	Mean Temp °C.	Rock (grams)	$CaCO_3$ (grams)	$CaCl_2$ (grams)	Water sol. alk. calc. to K_2O	% recovery of alkalis
I	1	950	100	100	25	0.719	6.66
II	2	950	100	100	50	0.562	5.20
III	2	1000	100	100	75	1.35	12.50
IV.	2	980	100	150	25	1.46	13.33
V	2	980	100	150	50	3.02	27.98
VI	2	950	100	150	75	7.03	65.09
VII	2	950	75	225	25	5.19	48.04
VIII	2	980	75	225	50	4.08	37.77
IX	2	980	75	225	75	7.78	72.04
X	2	950	75	225	112.5	10.67	98.81
XI	2	950	75	262.5	50	8.12	75.19
XII	2	950	75	262.5	75	8.64	80.00
XIII	2	980	75	262.5	112.5	10.23	94.72

At the direction of Professor McCormack a special mixture was made, consisting of 100 grams of rock, 10 grams of calcium fluoride, and 15 grams of sulphuric acid. The sulphuric acid was incorporated into the mixture just as was the calcium chloride in the previous work. This was heated up slowly to a temperature of 600°C, and then treated in the usual manner. The yield was 0.946% of total alkali calculated to potassium sulphate, and represented a recovery of 8.76%. No further work was done along this line.

RESULTS

Referring to the preceding table, two empirical mixtures stand out as giving commercial results. These are Nos. X and XIII. The recoveries as shown are based on total soluble alkali content calculated to potash. To get the true potash recovery correction should be made for the soda contained. The total recovery is so near to 100% that no serious error will be introduced in assuming that all of the soda is recovered, and not quite all of the potash. Subtracting the soda will give the approximately correct potash recovery. The error will tend to show rather less than the actual result. On this basis the potash recovery is:-

No. X.....98.39%

No. XIII.....91.68%

The mixture represented by No. X is therefore the one recommended for the successful operation of the process. There are several points of advantage that indicate commercial possibilities at

present prices. A large deposit of the rock is located in the state of Georgia not far from limestone and coal. The rock is very soft; power and machinery costs for grinding would therefore be low. Calcium chloride only would have to be shipped in. A market for the product is at hand, as the state of Georgia is one of the three greatest consumers of potash fertilizer. The rock itself possesses the distinct advantage of being unusually low in soda, which, for the production of commercial potassium chloride would obviate a fractional crystallization to remove the sodium chloride.

TENTATIVE COMMERCIAL PLAN.

The most favorable locality for the erection of a plant to carry out this process would be as near as possible to the raw materials. Since limestone and calcium chloride are used in such large quantities, it is essential that freight costs be reduced as far as possible by wise choice of locality. Sources of suitable water and coal are also important.

Rock and limestone are to be delivered to the plant in lump form. These are dumped on the stock piles and elevated as desired by conveyors to hoppers above crushers. The lumps are broken by the crushers, run by gravity and belting to ball mills where they are reduced to about 100 mesh.

The finely ground rock and limestone are run by belt or conveyors to stock bins, from which they are taken as desired. Rock and stone are brought to an automatic scale which weighs out pre-determined amounts of each. A belt and chute discharges the mixed powder to an edge runner.

Here the concentrated solution of calcium chloride is run in from a measuring tank connected with the stock solution tank above.

After sufficient mixing in the edge runner, the damp mass is charged into rotary cement kilns, about six feet in diameter and sixty feet long. Here the material is heated by a blast of powdered coal and air to the desired temperature and the rate of revolution is so regulated that two hours are required for the material to pass through the furnace.

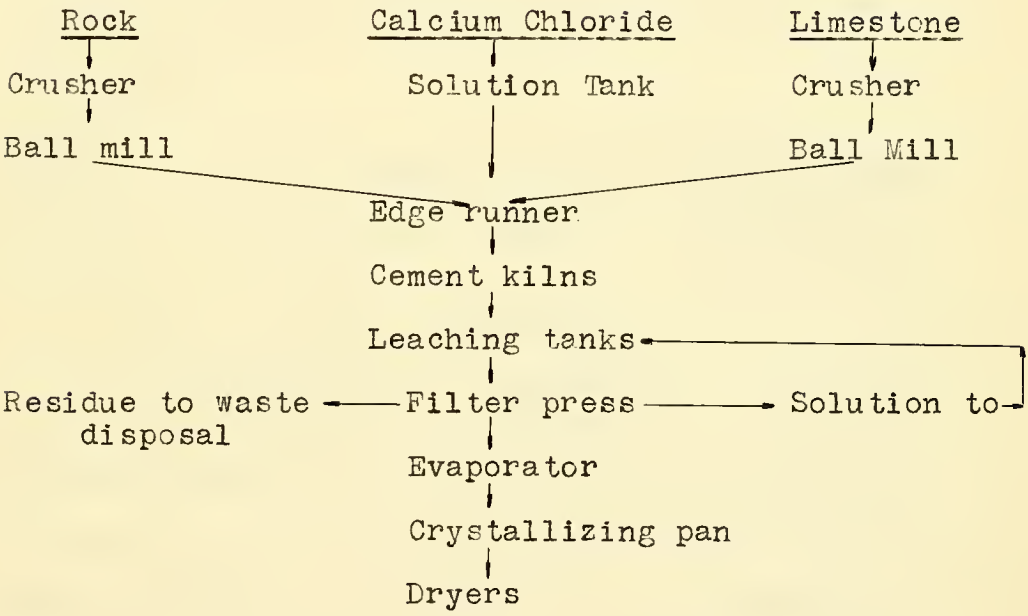
The hot material leaving the furnace drops into a chute which takes it to leaching tanks containing sufficient water to make a thin sludge of the mixture. The heat of the material from the furnace will be sufficient to warm the water so as to get more efficient extraction. Tanks of the Pachuca or others of the air-stirred types are to be used. After leaching the thin sludge is pumped to filter presses. Sweetland and self-dumping presses with a traveling belt below to remove the press-

cake is the equipment recommended for this work. The belt will discharge into a hopper from which cars taking waste to the dump will be filled.

The solution from the presses is to be run back to the leaching tanks until it is of sufficient concentration in potassium chloride to be profitably evaporated.

Evaporation will take place in a large double-effect evaporator working on the exhaust steam from the power plant. A crystallizing or finishing pan will handle the thick solution from the evaporator. After crystillization there remains only to dry the salt in a drum dryer, and sack the finished product.

The following flow-sheet will serve to make clear the foregoing:-



ESTIMATE OF PLANT AND OPERATING COSTS, AND PROBABLE PROFITS.

A large part of the equipment would be very similar to that of a cement mill so part of the equipment cost was easily calculated from data of that industry.

Cost for a Plant to Treat 75 tons of Rock per Day.

Crushing and grinding machinery.....		$10,950.00
Two stone crushers No. 5.....	$3,700.00	
Two ball mills, 5 by 10 ft.....	6,000.00	
One edge runner.....	825.00	
Calcining machinery.....		9,875.00
Two rotary kilns, 6 by 60 ft.		
Leaching tanks.....		6,000.00
Filter presses, three.....		7,500.00
One double-effect evaporator.....		5,000.00
One crystallizing pan.....		1,200.00
One dryer for crystals.....		1,200.00
Building, including piping, conveyors, belting, shafting, etc.....		35,000.00
Power plant.....		20,000.00
Total cost of plant...		$ 86,725.00

Operating Cost per Day.

Depreciation - 100%	$240.90
Labor	60.00
Cost of calcium chloride	1,500.00
Cost of limestone	200.00
Cost of rock	75.00
Cost of fuel	225.00
Taxes and incidentals	10.00
Management and selling	25.00
Total cost per day	$2,335.90

On the basis of a 95% recovery, or a production of 7.35 tons of potassium chloride per day the

Cost per ton of KCl.....$317.68

At present prices of potassium chloride, $360.00 per ton.

Profit per ton of KCl..... $ 42.32

Profit per day..... 317.40

The two largest items are those of depreciation and cost of calcium chloride. Depreciation

was figured at 100% on the investment with the idea in mind that the war and present prices would continue for another year. Should the war continue for longer than this time, plant cost could be entirely written off the books within the year. The figure for calcium chloride was based on market quotations of $11.38 per ton of 80-85% solution. There is little doubt that large consumers could obtain far better prices than this, with an attendant increase in profits.

This process could only be worked on a satisfactory commercial basis in war times and is not to be at all advised when potash prices are down to normal.

BIBLIOGRAPHY

Anonymous: The preparation of potash from feldspar and other sources. - Chemical News, 110. p. 175 (1914).

Bailey, Gilbert:
The Saline Deposits of California - California State Min. Bur. Bull. 24, 216 pp., 1912.

Burd, J. S.
The Economic Value of Pacific Coast Kelps - Calif. Univ. Exper. Sta. Bull. 248, Feb.1915.

Butler, B.S.and Gale, H.S.
Alunite, a newly discovered deposit near Marysvale, Utah - U. S. Geol. Survey Bull. 511, 64 pp., 1912.

Cameron, F. K., and others,
A preliminary report on the Fertilizer Resources of the United States - Doc. 190, 62nd Cong. 2nd Sess., pp. 27-48, 124-128.

Kelp and other sources of potash - Franklin Inst. Jour., vol. 176, No. 4, pp. 347-383, Oct. 1913.

Possible sources of potash in America - Franklin Inst. Journ. Vol. 180, pp. 641-651, 1915.

Cresswell, C.G.
Possible sources of potash - J. Soc. Chem.Ind. Vol. 34, pp. 387-393, 1915.

Cushman, A.S. and Coggeshall, G.W.
The production of available potash from the natural silicates - Eighth International Cong. App. Chem., vol. 5, pp. 33-49, 1912.

Feldspar as a possible source of American potash - Chem. Eng., vol. 21, pp 5-11, Jan. 1915.

Merz, A. R.
On the composition of giant kelps - Jour. Ind. and Eng. Chem. vol. 6, No.1, pp.19-20, Jan. 1914.

Merz, A. R. and Lindemuth, J.R.
The leaching of potash from freshly cut kelp - Jour. Ind. and Eng. Chem. vol. 5 No. 9 - pp.720-730, Sept.1913.

Phalen, W.C.
Occurrence of potash salts in the bitterns of the Eastern United States - U.S.Geol. Survey Bull. 530, pp. 313-329, 1913.

Potash salts, their uses and occurence in the United States. - U.S.Geol.Survey - Mineral Resources 1910, pt.2 pp.747-767, 1911.

Potash salts - Summary for 1911 - U.S. Geol. Survey Mineral Resources, 1911, pt. 2, pp. 889-917, 1912.

Potash salts - Summary for 1912.- U.S. Geol. Survey Mineral Resources, 1912, pt.2 877-908 1913.

Potash salts - Summary for 1913.- U.S. Geol. Survey Mineral Resources, 1913, pt.2 pp. 85-107, 1914.

Phalen, W.C.: - Potash salts - Summary for 1914 - U.S. Geol. Survey Mineral Resources, 1914 pt. 2, pp. 9-34, 1916.

Ross, Wm. H.
Extraction of potash from silicate rocks - U. S. Dept. of Agr. Bur. Soils Circ. 71, 10 pp. July 16, 1912.

Waggaman, WH.
Alunite as a source of potash - U.S. Dept. Agr. Bur. Soils Circ. 70, 4 pp. July 31,1912.